

7 Coastal Shrimp Farming in Thailand: Searching for Sustainability

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Abstract

Shrimp farming in Thailand provides a fascinating example of how the global trade in agricultural commodities can produce rapid transformations in land use and resource allocation within coastal regions of tropical developing nations. These transformations can have profound implications for the long-term integrity of coastal ecosystems, and represent a significant challenge to government agencies attempting to manage land and water resources. Thailand's shrimp-farming industry has suffered numerous regional 'boom and bust' production cycles that created considerable environmental damage in rural communities. At a national scale, these events were largely masked, however, by a shifting cultivation strategy and local adaptations in husbandry techniques. This chapter outlines the need to upgrade planning systems, improve water supply infrastructure and enhance extension training services within coastal communities to address ongoing systemic environmental management problems within the Thai shrimp-farming industry.

Introduction

In Lewis Carroll's *Through the Looking Glass*, the Red Queen tells Alice that 'in this place it takes all the running you can do to keep in the same place'. This phrase has been used to illustrate a variety of natural and social phenomena (Van Valen, 1973) and it also aptly describes the history of shrimp farming in coastal Thailand. This nation has been a leading global producer of farmed shrimp since 1992 (FAO, 2002), but the industry has been plagued by persistent environmental problems stemming from a combination of natural resource degradation and associated viral disease outbreaks (Szuster and Flaherty, 2002).

Environmental problems have created widespread crop failures throughout Thailand, but a predicted national-level collapse in farmed shrimp production has not occurred (Dierberg and Kiattisimkul, 1996; Vandergeest *et al.*, 1999). This chapter traces the development of shrimp farming in Thailand. It argues that the Thai aquaculture industry has for many years managed to avoid a national-scale collapse in shrimp production by shifting farm sites and modifying husbandry techniques. Although these strategies have succeeded in maintaining overall production levels, underlying problems related to planning, infrastructure and social organization continue to exist and

threaten the long-term sustainability of coastal shrimp farming in Thailand.

History of Coastal Shrimp Farming in Thailand

Thailand possesses over 2700 km of coastline and a tropical climate ideal for farming marine species such as shrimp. Basic biophysical factors are important, but the presence of appropriate aquaculture technologies, low agricultural wages and the availability of government tax incentives were also critical in supporting the development of shrimp farming in Thailand (Kongkeo, 1995). The shrimp-farming industry has gone through several distinct developmental phases that are reviewed below to illustrate the ability of Thai aquaculturalists to innovate and respond to changing environmental and socio-economic conditions.

Pre-expansion phase (1930–1971)

Shrimp farming was probably introduced to coastal Thailand by Chinese immigrants during the 1930s (Tookwinas, 1993). These early farms (called *thammachaat* or 'natural farms') applied traditional techniques that involved flooding low-lying coastal paddy fields during the dry season. Wild shrimp within the seawater were captured during this process and retained until the paddy fields were drained prior to planting a wet-season rice crop. Enclosures were large (30 ha or more) and a limited amount of daily water exchange was provided by natural tidal flows. Traditional farming techniques were inherently a polyculture because seawater provided the entire supply of shrimp seed and farmers exerted no control over species composition. Tidal flows also provided naturally occurring food organisms to sustain the captured shrimp during the culture period. Traditional shrimp farming requires no special technical skills or infrastructure, and input costs are minimal due to the use of naturally occurring seed stock and food. Yields are low (approximately 200 kg/ha/year), due to an absence of stocking control and

poor survival rates. Species cultured in this manner include the banana shrimp (*Penaeus merguensis*), Indian white shrimp (*P. indicus*), school shrimp (*Metapenaeus monoceros*) and black tiger shrimp (*P. monodon*).

Simple, traditional shrimp-farming techniques were modified during the late pre-expansion phase. New shallow shrimp ponds were constructed within coastal mud flats and numerous salt farms were also converted to shrimp production after World War II. This conversion was largely motivated by depressed salt prices, and more than 50% of the salt farms in the upper Gulf of Thailand region had been converted to shrimp production by the late 1960s (Csavas, 1994). Pond enclosures are still large in modified traditional systems (5 ha or more), but yields can reach 400 kg/ha/year by exercising limited control over fry stocking, improving water management and applying manure or chemical fertilizers to induce algal blooms. Only a small number of modified traditional shrimp farms continue to operate in Thailand today because of the modest harvests associated with this culture system (Pillay, 1997). Environmental damage associated with traditional shrimp farming is generally limited, but a large amount of intratidal land is needed for pond enclosures and this requirement can affect coastal habitats such as mangrove.

Early expansion (1972–1987)

Shrimp farming continued in a largely traditional form in Thailand until the early 1970s, when the Thai Department of Fisheries began experimenting with semi-intensive monoculture techniques (Katesombun, 1992). This modified culture system provided higher yields and was widely adopted in coastal areas already supporting traditional shrimp farms. Black tiger shrimp were the focus of semi-intensive husbandry experiments because this species possesses a high export value and is able to grow quickly under artificial conditions (Pillay, 1990). Another factor was the successful production of hatchery-raised black tiger shrimp postlarvae by Thai personnel trained in Japan. This breakthrough, in conjunction

with the development of improved feeds and husbandry techniques, set the stage for a dramatic expansion of shrimp farming in coastal Thailand (Liao, 1992).

Semi-intensive shrimp culture uses pond enclosures that are smaller than traditional farms (1–8 ha), but this system provides significantly higher yields (up to 1000 kg/ha/year). This increase in productivity is gained through the use of hatchery-raised fry, supplementary feeding and a limited degree of mechanical water management provided by low-lift axial flow pumps to supplement the water exchange provided by tidal action (Tookwinas and Ruangpan, 1992). Construction costs are higher due to the need to construct levees or dykes, but the pond enclosures are more uniform, which provides additional control over the grow-out environment (Pillay, 1993). The quality of effluent released into the surrounding environment by semi-intensive operations is usually poorer than that of traditional farms, and overall environmental impacts are more pronounced due to the increased culture intensity (Miller, 1996, unpublished Masters thesis). However, coastal habitats such as mangrove can be less affected by semi-intensive operations if sited in supra-tidal areas that possess soil and drainage characteristics that are better suited to aquaculture (Menasveta, 1997).

Shrimp boom (1988–1995)

The introduction of the semi-intensive culture systems to Thailand was quickly followed by the development of intensive farming techniques (called *phattana* or 'developed farms'). This technology was introduced from Taiwan and features smaller ponds (0.16–1.0 ha), the use of hatchery-raised shrimp fry at high stocking densities, mechanical aeration, prepared feeds, fertilizers, chemicals and antibiotics (Flaherty and Karnjanakesorn, 1995). Average farm yields increased to as much as 2000 kg/ha/year from 1987 to 1999 and total annual farmed shrimp production also skyrocketed (Fig. 7.1). In addition to favourable biophysical conditions and the availability of Taiwanese intensive farming technology, the Thai 'shrimp boom' was supported by Thai government policies and international development agencies such as the Asian Development Bank (Flaherty and Vandergeest, 1998). These institutions provided significant assistance to the emerging shrimp aquaculture sector in areas such as financial support to potential farmers, aquaculture research and extension services and infrastructure construction in coastal areas (e.g. roads and canals).

Intensive culture techniques were first

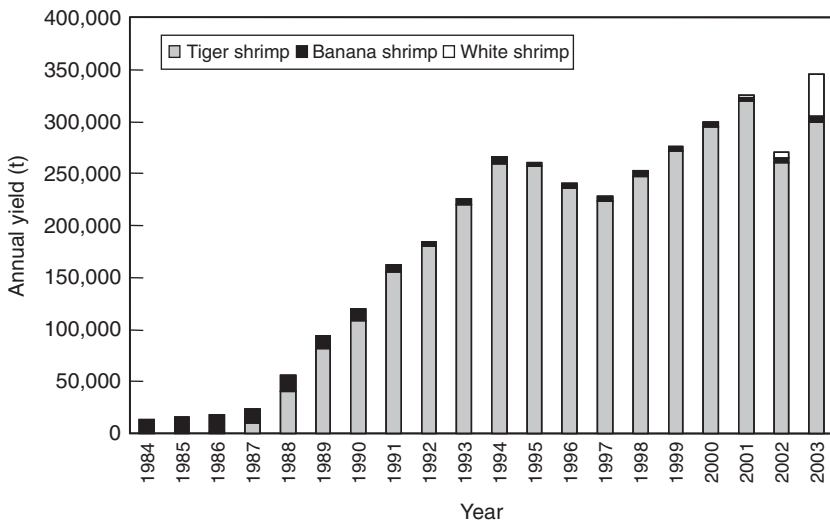


Fig. 7.1. Farmed shrimp production in Thailand, 1984–2003.

adopted in coastal areas surrounding the Upper Gulf of Thailand from 1987 to 1989. Most of these farms were small (less than 5 ha) and constructed on existing traditional shrimp farms, salt pans or wetlands. More than 80% were abandoned after only a few years of operation as a result of environmental degradation, viral disease problems and a lack of experience with intensive shrimp husbandry techniques (Jenkins, 1995). Derelict shrimp ponds became a common sight in Samut Prakarn and Samut Sakhon provinces at this time, with pond bottom soils contaminated by salt and chemical residues (Beveridge and Phillips, 1993). Although a small number of abandoned shrimp ponds were used to grow lower-value species such as fish or crab, many remained idle or were converted to non-agricultural land uses such as housing or manufacturing.

After the collapse of shrimp farming in the Upper Gulf of Thailand region, the geographic focus of shrimp farming moved to the eastern and southern coastal regions. These areas generally possess better soil and water supply characteristics than sites near Bangkok, and a large number of new farms were constructed during the early 1990s (Jory, 1996). The Thai government also recognized the emergence of serious environmental problems in the shrimp aquaculture sector during the early 1990s (e.g. mangrove destruction, soil degradation, water pollution) and responded by supporting research into revised aquaculture techniques and natural resource management practices (Kongkeo, 1997). Initiatives supported by the Thai government and agencies such as the World Bank and the Food and Agriculture Organization of the United Nations included training and extension services for small-scale aquaculturalists, research into water recycling and zero-discharge farming techniques, mangrove reclamation in abandoned shrimp-farming areas, seawater irrigation systems and research into shrimp disease and the breeding of domesticated species (MIDAS Agronomics, 1995).

There is no doubt that the management strategies, extension programs and infrastructure projects described above provided

immediate benefits to Thailand's shrimp farmers. However, their success in bringing long-term sustainability to the aquaculture industry is debatable. Total annual shrimp production continued to rise through 1995, but this increase was largely as a result of new farm construction in eastern and southern Thailand (Fig. 7.2). Improved management was not a major factor (Flaherty *et al.*, 2000). This shifting cultivation strategy was initially quite successful in maintaining national production levels, but, by 1995, most of the coastal land suitable for shrimp farming was already in production or abandoned. Total annual harvests declined in 1996 as a result of viral disease problems in eastern and southern Thailand (Department of Fisheries, 2002), and this led several observers to suggest that a national crash in shrimp production could be imminent (Flaherty and Karnjanakesorn, 1995; Dierberg and Kiattisimkul, 1996). Coastal shrimp production did, in fact, continue to fall during the latter half of the 1990s, but an important innovation allowed the shrimp boom to continue. Low-salinity shrimp-farming techniques were developed during the mid-1990s (Ponza, 1999, unpublished Masters thesis), and these would allow intensive shrimp farming to make a dramatic return to the Upper Gulf of Thailand region.

Low-salinity shrimp farming (1996–2002)

As crop failures became commonplace throughout coastal Thailand, the shrimp-farming industry began to search for alternatives to maintain production (Kaosa-ard and Pednekar, 1996). Crop failures in coastal areas during the early 1990s had a serious economic impact on novice shrimp farmers, who generally possessed very little aquaculture experience. They responded to this crisis in several ways. Some farmers attempted to raise additional shrimp crops, but this strategy simply compounded husbandry or environmental management mistakes that had led to the initial crop failures. Other farmers switched to safer crops such as freshwater fish or crab that involve fewer risks, but also smaller potential profits. Many individuals

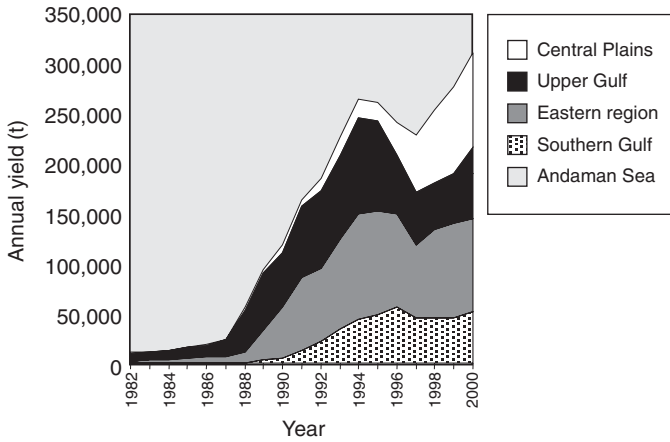


Fig. 7.2. Farmed shrimp production in Thailand by region (t), 1982–2000.

simply abandoned aquaculture and turned to off-farm employment in order to repay the large debts incurred from shrimp farming (Banpasirichote, 1993).

Relocating shrimp farms inland from disease-prone coastal areas also emerged as a response to widespread crop failures (Flaherty and Vandergeest, 1998). During the mid-1990s, farmers in Samut Prakarn and Chachoengsao provinces discovered that tiger shrimp could be grown in seasonally saline watersheds located near the coast (Szuster, 2001, unpublished PhD dissertation). Typically, these areas could support only a single dry-season shrimp crop because brackish water is unavailable during the rainy season. However, the development of low-salinity husbandry techniques allowed two, or even three, shrimp crops to be raised within a single calendar year (Flaherty *et al.*, 1999). Low-salinity farming techniques are generally similar to those used in coastal operations, but, while coastal farms use seawater to fill and replenish pond enclosures, low-salinity farms combine fresh water with hypersaline water purchased from coastal salt pans or saltwater concentrate operations (Miller *et al.*, 1999). Freshwater inputs are also used to offset evaporation and seepage losses over the grow-out period, and this can reduce salinity levels to near zero by harvest unless supplementary saline water or bagged salt is applied. Harvest on low-salinity farms

occurs earlier than on coastal operations as a result of falling salinity levels and the negative effect this has on shrimp health and development (Ponza, 1999). Given the shorter culture period and suboptimal growing environment, shrimp from low-salinity farms tend to be smaller and of poorer quality than shrimp produced in coastal areas.

The success of low-salinity techniques in seasonally saline areas was soon noticed by rice farmers in freshwater regions located further inland from the coast (Pongnak, 1999). Rice farmers realized that the high potential profits derived from shrimp production could easily offset the costs associated with trucking salt water to their land (Szuster *et al.*, 2003). Development opportunities were limited only by basic site suitability criteria, such as relatively flat terrain, suitable soils and a reliable source of water (Flaherty *et al.*, 1999). These factors led a large number of rice farmers in central Thailand to convert irrigated paddy fields into shrimp ponds during the latter half of the 1990s (Committee on Inland Shrimp Farming, 1998). It is difficult to estimate the extent of shrimp farming within freshwater areas of central Thailand during the late 1990s because information collected by the Royal Department of Fisheries does not distinguish between freshwater and brackish production sources. However, surveys conducted by the Thai Department of Land Development and the Department of

Fisheries suggest that low-salinity farms operating within freshwater areas could have accounted for as much as 40% (or approximately 100,000 t) of Thailand's total farmed shrimp output in 1998 (Limsuwan and Chanratchakool, 1998). Although it is difficult to assess the accuracy of this estimate, its magnitude alone indicates that the expansion of low-salinity shrimp farming within inland freshwater areas of central Thailand masked a very serious collapse of brackish-water shrimp production in coastal regions (Fig. 7.2).

The expansion of low-salinity shrimp farming into freshwater rice-growing areas of the Chao Phraya River Delta initially proceeded with little overt government support or scrutiny. This low profile disappeared when the Thai print media became sharply critical of low-salinity shrimp farming and the potential environmental damage this activity could produce within Thailand's most important agricultural region (Arunmart and Ridmontri, 1998). Many analysts suggested that low-salinity shrimp farms could produce soil salinization, water pollution and increased competition between agriculture and aquaculture for fresh water (Miller *et al.*, 1999; Pongnak, 1999). Following a rancorous debate between pro- and anti-shrimp-farming groups in the media, and the hasty completion of environmental impact studies, the Thai government banned shrimp farming within non-coastal provinces on the basis of a recommendation from the National Environment Board (Srivalo, 1998). Provincial governors in coastal provinces were subsequently instructed to identify and map brackish-water areas (where shrimp farming would be permitted) and freshwater zones (where shrimp farming would be restricted). In spite of the 1998 ban on low-salinity shrimp farming, the practice continued relatively uninterrupted over the following 2 years. Harvests may even have increased between 1999 and 2001 as the Thai government encouraged farmers to increase harvests to take advantage of high market prices stemming from a catastrophic collapse of shrimp production in Latin America (Bangkok Post, 2000a). The Thai shrimp-farming industry also lobbied strenuously

for a reversal of the ban on shrimp farming in freshwater areas during this period (Bangkok Post, 1999). Although government sources indicated that the restriction on this practice would be relaxed (Boyd, 2001), opposition from environmental groups, soil scientists within Thailand's Land Development Department and His Majesty King Bhumibol convinced the National Environment Board to reaffirm the ban (Samabuddhi, 2001). Progress on enforcing the ban has been slow, however, and a recent survey conducted by the Thai government suggests that many low-salinity shrimp farms continue to operate within freshwater areas (Samabuddhi, 2003).

Recent developments (2003–2004)

Thai government policies have certainly restricted the expansion of low-salinity shrimp farming within freshwater regions of the country (*The Nation*, 2001). This constraint has not prevented shrimp farmers from attempting to maintain overall production levels in the face of unresolved environmental problems and more rigorous quality restrictions imposed by major importers (Boonchote, 2003). Two recent strategies to maintain production are the conversion of low-salinity shrimp ponds to freshwater prawn culture in Nakhon Pathom and Suphanburi provinces (Szuster *et al.*, 2003), and the importation of the Pacific white shrimp (*Penaeus vannamei*), native to Latin America (NACA, 2003). Converting low-salinity shrimp farms to freshwater prawn production is a positive development that addresses soil salinization concerns, but the introduction of non-native shrimp species to Thailand is troubling. The Pacific white shrimp is popular with Thai shrimp farmers for its high yields and disease resistance characteristics. Existing Thai government regulations restrict the importation of this exotic species to research purposes only, but this control has been widely ignored in the interest of maintaining national shrimp production levels (Wangvipula, 2002). Farmers appear to have no difficulty in obtaining seed stock and the Thai Shrimp Farmers

Association estimates that up to 60% of all harvests in 2004 could be white shrimp (*Bangkok Post*, 2004). The importation and use of exotic shrimp could, however, disrupt host biotic communities or transfer exotic pathogens to native species such as the black tiger shrimp (Arthington and Bluhdorn, 1996). The Taura syndrome virus (TSV) is endemic in the Pacific white shrimp and has produced massive crop losses in Latin America (FAO, 1997). Although no cases of TSV transference to native shrimp species in South-east Asia have been documented to date, this pathogen may have already infected wild shrimp populations in Taiwan (NACA, 2003). Viral transmission pathways include the use of infected broodstock or seedstock, pond effluent disposal, pond flooding, shrimp escapes, transport to processing facilities and sediment or solid waste disposal (Lightner, 1996).

Strategies to Enhance Sustainability

Aquaculture planning

Thailand's coastal shrimp-farming industry finds itself at a critical juncture. In the face of trade sanctions by major overseas trade partners in Europe and America and growing domestic public scrutiny, many industry leaders and government decision-makers are aware that the sector must undergo a major transformation to achieve future success. An industry that is infamous for its 'slash-and-burn' approach to coastal land use, narrow focus on short-term profits and disregard for environmental regulations must now embrace stability, sustainability and regulation to secure access to international markets. This transformation can be achieved only through the development and implementation of formal planning structures and processes. Aquaculture zoning and other forms of integrated management have been proposed to enhance the sustainability of coastal shrimp farming in Thailand (Tookwinas, 1999), but this has been attempted in only a limited number of local pilot projects such as the recent Coastal Habitats and Resource Management initia-

tive (CHARM, 2003). There is little doubt that aquaculture zoning on a nationwide basis could protect environmental resources, minimize land-use conflicts and maximize shrimp production by siting farms in areas best suited for aquaculture. The Thai Department of Fisheries has carried out aquaculture suitability studies within major shrimp-farming areas in southern and eastern Thailand, and this information could support aquaculture zoning and other forms of integrated management. Thailand's Land Development Department (1999) has also investigated environmental conditions in coastal areas and recommended that shrimp farm construction be restricted to areas possessing soil parent materials with a conductivity of 2 mS/cm or greater (measured at 1.5 m below the surface). This action could mitigate potential impacts related to soil salinization and restrict shrimp farms to less productive agricultural areas where saline sediment lies relatively close to the surface. Although a complex regulatory environment will probably slow the emergence of effective aquaculture planning in Thailand (MIDAS Agronomics, 1995; Flaherty *et al.*, 2000), the identification of specific shrimp farm zones could impose a degree of stability on the industry and provide a focus for infrastructure and training programmes that are needed to support sustainable shrimp-farming practices.

Water supply infrastructure

Clean, plentiful water supplies are essential for successful aquaculture in the same sense that fertile soils represent the basis for agricultural crop production. The development of aquaculture water supply systems in Thailand, however, has been largely unplanned and has evolved by adapting the existing infrastructure, originally designed to support rice cultivation (Braaten and Flaherty, 2000). Exceptions to this include a small number of large, government-supported seawater irrigation projects that provide separate water supply and waste treatment infrastructure for coastal shrimp farmers in eastern and southern Thailand

(Tookwinas and Yingcharoen, 1999). Small irrigation canals serve as the only option for both water supply and wastewater disposal in all other shrimp-farming areas. The water pollution and disease transference implications of this practice are obvious, but the uncoordinated development of shrimp farming in Thailand has left most small-scale farmers with no alternative to the existing water distribution system (Beveridge and Phillips, 1993). Farmers accept that their water supplies are contaminated and have attempted to mitigate disease concerns by reducing water inputs during the culture period, applying antibiotics and switching to species such as the Pacific white shrimp with different disease resistance characteristics. Although these strategies can provide some short-term relief, viral disease outbreaks remain a constant threat that is magnified by the presence of inadequate water supply systems and sub-standard water management practices (Szuster *et al.*, 2003).

As the lead government agency charged with the responsibility for constructing and maintaining Thailand's irrigation infrastructure, the Royal Irrigation Department has traditionally focused on the needs of agriculture in general, and wet rice paddy production in particular. Aquaculture has a very low profile within the Royal Irrigation Department. The water supply needs of shrimp farmers are viewed as the responsibility of the Department of Fisheries. This division of responsibilities ignores the fact that aquaculture is a dominant water user group in many coastal areas (Szuster, 2001). More effective management of water supply infrastructure within coastal Thailand is needed, and should be a priority in areas specifically zoned for aquaculture. A telling example of the current lack of coordination between Thai government agencies with respect to aquaculture water supplies is the recently completed Bangpakong River dam in eastern Thailand. This dam was planned and constructed by the Royal Irrigation Department to limit natural saltwater tidal flows in the Bangpakong River during the dry season (Kasetsart University, 1994). Dry-season saline intrusion in upstream areas limits irrigation opportunities and agricul-

tural production, but is a defining ecological characteristic of low-gradient river systems in South-east Asia. The presence of seasonally saline flows in the Bangpakong River also facilitated the development of low-salinity shrimp farms that can be found more than 100 km upstream of the Gulf of Thailand. Aquaculture water use, however, was not given a high priority by the Royal Irrigation Department during the planning of the Bangpakong River dam project (Kasetsart University, 2000). This led to a significant investment in water supply infrastructure that not only ignored the needs of shrimp farming, but also seriously affected the hydrology and natural ecology of the Bangpakong River ecosystem (*Bangkok Post*, 2000b). Improved water supply systems are a fundamental requirement for the evolution of sustainable shrimp-farming practices, but additional infrastructure spending does not guarantee success. Improved consultation and cooperation among the Thai government agencies responsible for water resource management are also needed to effectively plan new infrastructure investments and manage existing water supply systems to the benefit of both aquaculture and agriculture.

Social organization

In contrast to the significant corporate presence within India and Latin America, the Thai shrimp-farming industry is dominated by small, independent owner-operators (Flaherty *et al.*, 1999). Shrimp farmers are typically former agriculturalists, fisherfolk or small-scale business investors with little or no previous background in aquaculture (Flaherty *et al.*, 2000). Most operations are managed as family farms, with little or no assistance from hired farm labour or professionals such as biologists or veterinarians. Access to credit is also limited because of the modest scale of the operations and the financial risks associated with shrimp farming (Vandergeest *et al.*, 1999). A small number of shrimp farms are owned by outside investors who lease land within farming communities to construct larger operations (CORIN, 2000), but this situation is unusual

in most areas. Several large corporate farms were constructed in Thailand during the 1990s (primarily in the southern region), but most of these operations subsequently closed as a result of environmental degradation, viral disease outbreaks and unsatisfactory contract-farming arrangements (Boonchote, 2003; Vandergeest *et al.*, 1999). The corporate presence in the Thai shrimp aquaculture industry is now largely restricted to the manufacture of shrimp feed and processing for market rather than to the grow-out phase. A small number of government shrimp-farming projects, such as the Kung Kraben Bay Royal Initiative, have also been developed. These projects typically involve several hundred small family farms organized to take advantage of the communal water supply and waste treatment infrastructure. These government projects are expensive to construct, however, and less than 5% of all shrimp farms currently have access to seawater irrigation facilities (Tookwinas and Yingcharoen, 1999).

The small-scale and highly mobile nature of shrimp farming in Thailand has allowed the industry to increase national production in spite of serious economic and environmental challenges. This organizational structure possesses inherent weaknesses, however, that must be addressed if the industry is to become more stable and sustainable. Substantial effort has gone into the creation of best management practices and a voluntary Code of Conduct for shrimp farmers (Boyd, 1999; FAO and NACA, 2000). The development of these initiatives stems from an acceptance that many existing shrimp farm management practices are detrimental to environmental quality and even potentially hazardous to human health (Boyd, 2003). Major proponents of the Code of Conduct include the Thai Department of Fisheries and major aquaculture industry groups (e.g. the Thai Marine Shrimp Farmers Association, the Thai Frozen Foods Association, the Thai Food Processors Association and Global Aquaculture Alliance). Transferring this information on improved husbandry and environmental management practices to a large cadre of independent-minded rural farmers has

proved to be difficult (CORIN, 2000). Training courses and manuals have been developed (Prompoj, 2002; Wailailak University and the Thai Shrimp Network, 2002), but only a relatively small number of farmers will be enrolled in Code of Conduct implementation pilot projects over the next 5 years (Tookwinas, 2002). A large number of farms will not qualify for certification under the Code of Conduct because their operations are too small to support essential infrastructure such as treatment ponds. Many other farmers may not participate because they do not recognize the financial benefit of implementing the code (Ampornpong, 2002, unpublished MSc thesis).

These difficulties highlight the need for both improved government extension services at the local level and support for the organization of local shrimp-farmer groups. Duplicating the infrastructure and techniques used by neighbours is a common management strategy adopted by many Thai shrimp farmers (Flaherty *et al.*, 1999). Seminars provided by feed or chemical sales agents have also been used in the past to spread knowledge of husbandry techniques in rural areas. Relatively few farmers have attended Thai government-sponsored aquaculture seminars or belong to local cooperative shrimp-farmer groups (Miller *et al.*, 1999). A small number of organizations such as the Surat Thani Shrimp Farmers Club have emerged to deal with common husbandry, environmental management and socio-economic concerns, but it is notable how few cooperative shrimp-farmer groups exist at the local level in Thailand. Most shrimp farmers also have limited contact with staff from the Department of Fisheries and many are proud of their ability to achieve success 'on their own' with little or no outside assistance (Miller *et al.*, 1999). This attitude has been attributed to weak group cohesion within Thai society that limits cooperation and the spread of knowledge outside of an individual's immediate close relations (CORIN, 2000). It is important that this attitude be overcome. Future improvements in sustainability depend on better cooperation between government agencies and rural communities, and greatly

improved collaboration among local groups of shrimp farmers. More emphasis on capacity building within local government extension services and community shrimp-farmer organizations is also required. Initiatives such as the best management practices and the Code of Conduct are useful management tools, but their success in improving the overall environmental performance of the shrimp-farming industry will largely depend on supplementary measures that support effective farm-level social organization and cooperation.

Conclusions

The evolution of shrimp aquaculture in Thailand has been characterized by a constant search for unexploited areas to replace farm sites degraded by poor husbandry practices, pollution or disease. Over the past 15 years, the focus of farming activities has shifted from the Upper Gulf of Thailand to eastern and southern Thailand, and finally inland to freshwater areas of central Thailand. Local technical innovations such as low-salinity culture techniques supported a move into freshwater areas, and non-native Pacific white shrimp have recently been introduced to areas suffering from viral disease problems in the traditional black tiger shrimp crop. Shifting cultivation strategies and technical innovations have been successful to the extent that national farmed shrimp production has increased over the past 10 years (FAO, 2004), but environmental concerns associated with water pollution, land salinization, land-use conflicts and disease transference remain unresolved (Szuster and

Flaherty, 2002). This situation presents a serious challenge to the shrimp-farming industry because few opportunities exist for expansion in coastal areas and the ban on low-salinity culture has removed expansion opportunities within freshwater regions (Szuster *et al.*, 2003). The shifting cultivation strategy that supported the Thai 'shrimp boom' appears to have run its course, and serious consideration must now be given to measures that will allow the industry to create a sustainable future within existing shrimp-farming areas.

The issues we have noted as requiring critical attention largely relate to group cooperation and social organization. Indeed, it is reasonable to suggest that a large majority of the strictly technical concerns preventing the evolution of more sustainable shrimp cultural practices have been resolved over the past 20 years (Boyd and Clay, 1998). This includes advances in husbandry practices, domesticated broodstock supplies, disease resistance, siting criteria, water supply infrastructure and waste treatment techniques. Structural concerns within the Thai natural resource management system were overlooked during the shrimp boom years, but the end of this gold rush mentality has highlighted the need for stability, regulation and sustainability in all regions supporting aquaculture. Issues such as aquaculture zoning, water resource management and capacity building within local extension services and farmers' organizations can no longer be ignored. Ultimately, the future of the Thai shrimp-farming industry depends on how effectively these issues are managed because the short-term strategies of the past will clearly not sustain the shrimp-farming industry in the future.

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